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THE JULIAN-CUYAMACA BARK-BEETLE OUTBREAK

Preliminary Report of Investigative Studies - 1948

by

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THE JULIAN--CUYAMACA BARK-BEETLE OUTBREAK

Preliminary Report of Investigative Studies - 1948

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THE JULIAN--CUYAMACA BARK-BEETLE OUTBREAK

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INTRODUCTION

Serious outbreaks of the five-spined engraver beetle, Ips confusus Lec., have occurred from time to time in the pine areas of southern California leaving in their wakes large numbers of dead and dying trees. The most recent of these, and perhaps the most severe of any yet recorded in this section, occurred in the Coulter pine areas of San Diego County near Julian. In fact, epidemic killing prevailed which, during the peak in 1947, accounted for well over 6,000 dead and dying pines in an area of some 20,000 acres.

The aggressive character of this outbreak, similar in many respects to other recent outbreaks in the California pine region yet different because of its attack upon Coulter pine in this more southerly latitude, stressed the need for specific studies as a basis for understanding it. Much information was needed on origin, breeding characteristics, and other factors underlying the outbreaks as a basis for preventing or limiting future outbreaks.

The opportunity for studying this epidemic in some detail was provided following the institution of control measures during the winter and spring of 1948 by the California State Division of Forestry. With large numbers of infested trees felled for control by burning, stem sections were examined critically for infesting species, abundance, and distribution. Logging activity by small sawmills provided fresh slash material from which detailed information was taken on the life history and habits of the beetle, following control work. Continuous observations were made on the flight and behavior of adult Ips in attacks on living trees to determine if there were seasonal variations in aggressiveness.

Observations also were made on certain other primary insects believed of importance in the current outbreak. Those included were: The red turpentine beetle, Dendroctonus valens Lec.; the western pine beetle, D. brevicomis Lec.; and flatheads, Melanophila sp. Consideration was given to the incidence of mistletoe, Cronartium rust fungus, and a root fungus, Fomes annosus, as killers or weakening agents.

These studies were initiated early in February and continued into the fall of 1948. They were centered at the Julian Ranger Station of the California State Division of Forestry. Facilities provided through the cooperation of this Division aided materially in carrying out this detailed study.

PAST OUTBREAKS

The number of recorded infestations in the southern California stands is few, but evidence indicates that bark-beetle activity is perhaps as old as the forest areas. The first recorded outbreaks were reported by cattlemen (the Mendenhall brothers) in 1908, but no continuous records were established until 1923. Since then, there have been several periods in which the killing has risen to such a degree that suppressive measures appeared necessary. Epidemic activity by the western pine beetle and Ips in the Julian area was first noted by F. P. Keen on September 2, 1915. He reported (Hopk. U. S. #13282), "Bark beetles are doing a tremendous amount of damage. On one hillside (north of Julian) about half the trees had been killed with new infestation abundant." Beetles collected from Coulter pines at that time were first identified by Dr. A. D. Hopkins as Dendroctonus barberi Hopk. It was later decided by Hopkins that this was not the southwestern pine beetle, D. barberi, but was the western pine beetle, D. brevicomis Lec. An epidemic which began in 1930 and extended through 1934 was controlled by CCC crews in 1933 and 1934, when 600 infested trees totalling 127,330 board feet were felled and burned. Following that, another flare-up occurred in the Pine Hills area in 1939 and 1940 after a fire, but evidently no suppressive measures were undertaken.

CHARACTER OF INFESTATION

Description of area and tree species

The infestation area includes approximately 23,000 acres of pine lands interspersed throughout 40,000 acres in Townships 13 and 14 South and Ranges 3 and 4 East, San Bernardino meridian. The region ranges in elevation from 4,000 to 6,500 feet over a gentle, rolling terrain broken only occasionally by peaks which rise sharply from the less precipitous surrounding countryside. To the east, the country drops sharply off into the Anza Desert State Park and Imperial Valley while to the west, the mountains fall gradually toward the Pacific Ocean some 40 airline miles away.

Coulter pine (Pinus coulteri), in association with oak, constitutes the major timber type of the region. Jeffrey pine (Pinus jeffreyi) replaces Coulter pine as the coniferous species of the association in the Cuyamaca unit, while ponderosa pine (Pinus ponderosa) is found in areas of the Pine Hills unit. The higher peaks and more moist northern aspects support a mixture of more tolerant conifers and sugar pine (Pinus lambertiana).

Type of killing

The pattern of insect loss followed no definite trend with regard to site or tree vigor. Losses occurred in pine stands over most of the area representing all types of sites found there. Stands on exposed dry ridges as well as those in the more moist valleys contained some insect-killed trees of all ages from 20 to 120 years. The greatest concentration of trees killed, excluding pole-size, centered around 50 years of age.

No consistent pattern could be discerned as to the type of kill throughout the region, i.e., group or individual tree killing. In some very heavily infested localities, entire hillsides were colored as a result of large groups of fading trees. Groups of from 400 to 600 infested trees were counted, while elsewhere throughout the area scattered kills were the only evidence of beetle activity.

Not all the trees attacked were completely killed. 11 percent of 118 infested trees examined in stem analysis investigations had only 33 percent, or less, of the crown length killed as a result of bark-beetle attacks, and these trees probably could be expected to continue living under normal circumstances. The remaining 89 percent of the trees examined with over one-third of their crowns killed probably could be expected to die as a result of the bark-beetle attack.

Table 1 shows the distribution of the amount of crown-length fade and bole-length infestation by Ips as found in 118 trees of random selection attacked in the fall of 1947.

Table 1.--Distribution of Faded Crown Length and Infested Bole Length as Found in 118 Pines Attacked in the Fall of 1947 by Ips Beetles.

% of Crown Length Faded and Bole Length Infested	Occurrence			
	Faded Crown		Infested Bole	
	No. Trees	%	No. Trees	%
10- 33	13	11	15	13
34- 66	35	30	47	40
67-100	70	59	56	47
Total	118	100	118	100

Insects responsible for primary killing

Ips was the genus of bark beetles responsible for most of the killing during the current infestation. Stem analysis records showed that 92 percent of all the trees examined had been attacked by Ips broods either in combination with other tree-destroying beetles or alone.

The losses attributable to Ips were caused by two species--Ips confusus Lec., the California five-spined engraver beetle, and Ips oregoni Eich., the Oregon engraver beetle.

While data are insufficient to be completely reliable, the results of five rearing records seem to indicate host preference by the different insect species. For example, examination of 168 Ips adults emerging from three Coulter pine samples aggregating nine square feet of bark area revealed that all were Ips confusus. Also, similar examinations of 195 Ips adults from infested Jeffrey pine revealed that 99 percent of them were Ips oregoni and 1 percent Ips confusus. Hence, it is shown from the limited sampling of representative infested material that Ips confusus apparently prefers Coulter pine and Ips oregoni prefers Jeffrey pine.

Further data from 118 infested trees showed that 67 percent of the tree mortality was caused by Ips alone, 6 percent by insects other than Ips; while 25 percent of the killing was the result of Ips in combination with other insects and 2 percent mortality resulted from unknown causes.

Two insects, the western pine beetle (Dendroctonus brevicomis Lec.) and the flat-headed borer (Melanophila sp.), were responsible for limited killing throughout the area. Most of the activities of these beetles was secondary in importance in trees already attacked by Ips. The red turpentine beetle was found in the basal portion of some of the trees mostly in the role of a secondary invader.

Table 2.--Percentage of Trees Killed by Various Beetle Combinations

Insects Responsible for Killing	% of Total Infested Trees Killed	
Ips spp. only	66.9	
Ips and D. b.	12.7	
Ips and Melanophila	3.4	
Ips and D. v.	3.4	
Ips, D. b., and Melanophila	2.5	
Ips, D. b., and D. v.	3.4	
		92.3
D. b. only	1.7	
D. b. and Melanophila	1.7	
D. b. and D. v.	0.9	
		4.3
Melanophila only		1.7
Unknown		1.7
Total		100.0

Relation to logging and improvement clearing

Ips confusus is a slash breeding beetle, and the history of most recent Ips outbreaks points to the presence of slash as a primary factor in the development of outbreaks. Slash, in quantity, was present in the Julian area just prior to the current outbreak.

The so-called non-commercial timber occupying most of the forest area around Julian was cut for lumber, probably under the impetus of the war and the accelerated demand for forest products as early as 1942. The Volcan Mountains, five airline miles north of Julian, were the scene of the first pine logging. During the spring of 1945, a small logging operation cutting approximately 2,000 to 3,000 board feet of Coulter pine a day created an abundant supply of slash in the Whispering Pines tract near Julian. More slash was laid down during 1946 and 1947 just north of Julian; commencing with the Eastwood tract, the operation moved eastward across the timbered country above Julian to Whispering Pines. Jeffrey pine was logged around the northern edge of North Peak in 1947 and earlier.

These logging operations, combined with a power-line clearing from Pine Hills to Descanso and scattered homesite clearings, created a vast quantity of fresh slash which proved to be an ideal medium in which tremendous numbers of Ips adults were reared under favorable breeding conditions.

Other factors possibly responsible for weakening and kill

Certain factors other than insects and climate have considerable bearing on the vigor and health of the pines in the Julian-Cuyamaca infestation area. Fungi and parasites, or semi-parasitic plants such as dwarf mistletoe, fall into this category.

No specific tests were conducted for the purpose of determining the effect of such agencies upon the pines of the area, but the evidence of fungi and mistletoe damage was so widespread throughout the area that some mention should be made concerning it.

Western dwarf mistletoe (Arceuthobium spp.) is quite widely distributed throughout the area, but most predominant on Coulter and Jeffrey pines in the transition zones between the coniferous forest type and the chapparal-chemise type bordering the desert proper. Apparently the greatest damage caused by dwarf mistletoe was limited to the formation of witches' broom and the killing of some infested limbs. By and large, dwarf mistletoe may be considered as an agent which weakens the tree and probably predisposes it to insect attack. Its presence, however, is not necessary to the establishment of Ips under epidemic conditions.

Several different fungi were noted as probable weakening agents of the Coulter and Jeffrey pines in the area. In some cases, evidence of root rot fungus (probably Fomes annosus) indicated that death may have been due to this fungus. Quite prevalent over the area, but apparently less destructive than the root rot were the stem rust, probably Cronartium harknessii, and a needle cast, probably Elytroderma spp.

CLIMATIC FACTORS PRECEDING INSECT OUTBREAK

Precipitation

The rainfall record for the past 19 years, as collected by a resident[1/] of Julian in connection with the Weather Bureau, shows marked fluctuations above and below the "normal" rainfall expected per year as derived from a 50-year average. Maximum deviations from the considered norm of 33 inches per year range from a high of 51 inches in the period from July 1936 to June 1937 and to a low of 14 inches in the period from July 1933 to June 1934.

An algebraic summation of the seasonal departure from the expected normal rainfall for the years from 1929 to 1948 reveals a rainfall deficit of 46 inches. Quite striking is the fact that 81 percent, or 37 inches, of the deficit occurred during the past seven years--from 1941 to 1948. This departure from the normal seasonal rainfall built up slowly, with minor fluctuations, from 1.6 inches below normal in 1941-1942 to 13 inches below normal in 1947-1948.

The six month spring (January to June) departure from the normal rainfall, which would be most important to the growth of the tree and, consequently, would affect its vigor and resistance, has been significantly greater during the past 19 years than the seasonal rainfall record would indicate. Over the period from 1929 to 1948 the spring months received 58 inches less rainfall than could normally be expected for that season of the year. Here again, the last seven years have been considerably drier than the 12 years preceding them. 97 percent of the spring rainfall deficiency, or 56 inches, can be accounted for in the years from 1941 to 1948.

Figure 1, evolved from rainfall data given in Table 3, shows the fluctuating nature of the seasonal rainfall as compared to the normal for 50 years and the spring rainfall departure under the same conditions from July 1929 to December 1948.

Of great significance is the apparent correlation of forest insect (Dendroctonus brevicomis and Ips confusus) outbreaks with the periods of greatest rainfall deficiency as indicated by the troughs on the graph. The apparent downward trend of the graph indicating a progressively drier climate may also be of significance, for the cumulative effect of the drought-like conditions, especially during the active growing season of the forest, probably can be considered responsible for a weakened stand condition and the opening wedge for the current outbreak.

1/ Fred Barnes, Manzanita Ranch, Julian, California.

Table 3.--Rainfall Data Summary, Julian, California

(Elevation: 4,222 Ft.)

Year-- July-June	50-Year Ave. 1879-1930	Seasonal Departure from Ave.	6-month Spring Departure	6-month Summer Departure
1929-1930	33.26 in.	- 3.29 in.	+ 3.31 in.	- 6.60 in.
1930-1931	do	- 6.87 in.	- 3.32 in.	- 3.55 in.
1931-1932	do	+11.04 in.	+ 2.14 in.	+ 8.90 in.
1932-1933	do	- 0.27 in.	- 5.82 in.	+ 5.55 in.*
1933-1934	do	-19.36 in.	-12.56 in.	- 6.80 in.
1934-1935	do	- 4.07 in.	- 4.07 in.	No record
1935-1936	do	- 1.75 in.	+ 8.22 in.	- 9.97 in.*
1936-1937	do	+18.47 in.	+ 8.48 in.	+ 9.99 in.
1937-1938	do	- 0.11 in.	+ 6.65 in.	- 6.76 in.
1938-1939	do	- 6.10 in.	- 7.17 in.	+ 1.07 in.
1939-1940	do	+ 2.74 in.	+ 2.08 in.	+ 0.66 in.*
1940-1941	No Record			
1941-1942	do	- 1.56 in.	-10.12 in.	+ 8.56 in.
1942-1943	do	- 1.51 in.	+ 2.25 in.	- 3.76 in.
1943-1944	do	+ 0.06 in.	- 0.16 in.	+ 0.22 in.
1944-1945	do	- 7.64 in.	- 7.33 in.	- 0.31 in.
1945-1946	do	- 6.70 in.	-13.19 in.	+ 6.49 in.
1946-1947	do	- 6.51 in.	-15.79 in.	+ 9.28 in.
1947-1948	do	-13.17 in.	-11.38 in.	- 1.79 in.
1948-1949	do		- 3.50 in.	
	Total:	-46.60 in.	-57.78 in.	+11.18 in.

*Partial record.

Relation to stand growth

Examination of increment cores taken from 42 representative pines in the area indicated that a correlation apparently exists between rainfall deficiency, annual diameter increment, and bark-beetle outbreaks. Marked reduction in diameter growth and a flare-up of bark-beetle activity coincide quite consistently with periods of rainfall deficiency over the past 19 years.

Figure 2 illustrates the growth rate determined from increment core studies and brings out the apparent relationship between rainfall, growth rate, and bark-beetle outbreaks that has existed in the Julian area for the past 19 years.

SEASONAL HISTORY AND HABITS OF IPS CONFUSUS IN COULTER PINE

Overwintering habits

Observations and records concerning the overwintering habits of Ips in the pines of the Julian-Cuyamaca infestation area from February to April, 1948 disclosed that the greater portion of the overwintering brood was passed in the callow adult to adult stages. Twelve brood counts involving the inspection of 28 square feet of bark area placed the brood stages at 89 percent adults, 8 percent pupae, and 3 percent larvae.

Ips adults were sometimes found in groups ranging from 10 to 35 per group. Records show that 64 percent of the feeding groups observed while making stem analyses were congregated under the bark just below the abandoned top of the tree suggesting a possible movement of the mature stages of the brood downward into the fresh food material.

Additional information concerning overwintering broods is summarized in Table 4.

Table 4.--Overwintering Brood Data

No. of Samples	Bark Area Examined (Sq. Ft.)	No. Attacks Per Sq. Ft.	Living Ips (Larvae-Adults) Counted	Brood Per Sq. Ft.	Brood Per In.	Egg Gallery Length Per Sq. Ft.
From Field Counts:*						
12	28	9.2	2,897	103.5	1.8	58.2 in.
From Emergence Data:**						
			Emerging Adults			
4	11.7	9.3	1,020	87.2	1.6	53.0 in.

* The field counts consisted of examinations of infested material as it was felled in the field by State control crews between February and March 1948. The bark was carefully removed, bit by bit, from a representative sample of infested material and a count of the Ips broods under the bark and in the phloem was made. The number of attacks was determined by counting the scored impressions of the attacks on the xylem. The scored impressions of the attacks also allowed gallery lengths to be measured.

** Emergence data were gathered from log sections cut from infested trees during February and March and placed in rearing cages located at the Julian Ranger Station. Two types of rearing cages were used during the study: (1) Sealed cardboard boxes with a mason jar inserted into a hole cut out of each box. The emerging beetles collected in the mason jar and were counted and disposed of easily; and (2) cages measuring 16x16x24 inches constructed of five-ply plyboard with ventilating apertures and an exit into a mason jar.

The data gathered from counts of field records is as follows: 2,897 living Ips of which 89 percent were in the adult stage; in the 12 field samples, a total of 3,439 Ips, both alive and dead, were counted. The difference of 542 represents Ips brood that had died or had been killed prior to the count. This represents a mortality factor of approximately 15.8 percent of the total brood. An over-all brood mortality factor of 29 percent was revealed by a comparison of all broods, dead and alive, from field counts and rearing cages.

Early flight and attacks

Unusually warm weather, ranging between 70° and 80° F., during the latter part of December 1947 and the early part of January 1948 undoubtedly had its effect in causing early emergence of overwintering Ips adults. Some emergence actually occurred during midwinter when new attacks were made. Observations during the week of January 19, 1948 by G. R. Struble, Entomologist, Berkeley Forest Insect Laboratory, and Floyd Lewis, Assistant Ranger, State Divison of Forestry, revealed egg galleries two to three inches long with eggs in a recently broken top. Later examination of this brood indicated that severe drying of this top had resulted in brood failure.

Green tops of Jeffrey pine left as a result of a very small cutting on the lower slopes of North Peak provided further evidence of Ips attacks resulting from unusually early emergence of overwintering adults. The slash was created during the middle of January, but it was not until February 19 that Ips work was detected in it. Eight samples of slash were marked and recorded for the purpose of following the development of the Ips broods they contained. Several days later, ten more slash records were set up.

When the first Ips attacks were noted in the January slash, the majority of them consisted of a nuptial chamber and three to four radiating egg galleries extending from ½ to 1½ inches in length per attack. Several pieces of slash contained galleries up to four inches in length. First instar larvae were present in several of the tops, but brood development in the majority of cases had progressed only as far as the egg phase. While field examinations of the slash material commenced too late to ascertain the date of the first attack, it is the writer's opinion that the original attacks occurred sometime in January. New attacks continued and broods were established in this slash material up to the middle of April.

The rate of brood development seemed to be dependent upon temperature, with little or no growth changes occurring during the colder periods. During the first field examinations when the daytime temperature averaged between 34° and 46° F., the broods appeared to be dormant. The temperature after the middle of March was much higher than in previous weeks, and the broods began to develop much more rapidly.

The position of the first seasonal brood under the bark with respect to insolation is apparently related to rate of brood development during the colder periods. Brood development was noticeably faster when that portion of the slash in which they were feeding was exposed to the direct rays of the sun. Progeny under the shady portions of a piece of slash appeared to develop one stage behind progeny growing under the exposed portions of slash

even though the attacks occurred at approximately the same time.

Slash that was so situated as to receive the direct rays of the sun produced broods which emerged during the first week of June. Peak emergence from the early samples did not occur, however, until the fourth week of June. By the sixth of July, most of the slash samples containing the broods resulting from the first flight of the overwintering Ips had emerged.

A composite picture of the general brood history of the first Ips generation developed from 18 slash records examined weekly from February through July is shown in the following diagram.

Table 5.--Brood Development of First Generation Ips Oregoni in Jeffrey Pine Slash

	January 1:15:31	February 1:15:29	March 1:15:31	April 1:15:30	May 1:15:31	June 1:15:30	July 1:15:31
Attack		92 Days (********)**********					
Eggs			120 Days **********				
Larvae				66 Days **********			
Pupae					23 Days ********		
Adults					27 Days **********		
Emergence						36 Days **********	
			173 Days (Approximately)				

Main flight and attack periods

Emergence records from 17 infested samples representing 51 square feet of bark area collected at various locations in the area during the season show emergence of the overwintering and subsequent broods developing the following schedule: Overwintering broods, exclusive of the pre-seasonal January emergence, commenced to emerge the latter part of March and reached their peak emergence between April 16 and May 10; subsequent broods emerged from breeding material almost continually until the end of November, with heavy emergence periods corresponding to the peak flight of each generation scheduled on approximately June 15, July 30, and September 1.

Living trees in this area were subjected to Ips attacks through the entire season of insect emergence and flight. The frequency of kill in living trees was slow at first. Nine pines scattered over the infestation area were observed to fade and die from the latter part of June to the middle of July. Killing rapidly increased to a peak between August and September when approximately 830 trees were killed. After September the frequency of kill slowly tapered off to an estimated 740 trees in October and 670 trees in November. An over-all total of 2,500 trees were attacked and killed by Ips from April through November in the Julian-Cuyamaca area.

Number of generations

Conditions conducive to breeding in fresh slash existed in the Julian-Cuyamaca area from April to September 1948. Continuous attacks occurred on the fresh slash and in standing trees throughout this period resulting in a constant supply of all developmental stages and overlapping generations of Ips. After September 15, new attacks recorded in slash material tapered off rapidly to no recorded attacks the month of October. Slash material laid down the first of October, however, eventually was partially attacked the last week in November.

Brood development and emergence records obtained throughout the season from five slash areas and 17 rearing cage records indicate four full generations and a partial fifth generation of Ips were produced during the period from January to November 1948 in the Julian-Cuyamaca area. These data indicate the dates for each generation to be as follows:

Table 6.--Calendar of Ips Generation Development--
Julian-Cuyamaca Area, 1948

Generation	Main Attack	Emergence			Days--Main Attack to Peak Emergence
		Begin	Peak	End	
I	April 14	June 1	June 15	July 6	60
II	June 15	July 23	July 30	Aug. 6	45
III	July 30	Aug. 20	Sept. 1	Sept. 8	33
IV	Sept. 1	Oct. 7	-	-	-
V (Partial)	Oct. 14-Nov. 15	Overwintering			

Data from five slash records established September 13 showed that the major portion of the fourth generation would overwinter in the adult stage. The full-grown larvae and pupae stages were present in the slash, but were considerably less numerous than the adults. Two of four recorded slash samples established October first contained moderate to heavy fifth generation Ips attacks by November 30. The attacks had produced egg galleries up to three inches in length and some eggs; no larvae were found. Examination of these slash samples on March 17, 1949, revealed that the two previously attacked

samples had failed to develop successful broods, but apparently the new attacks they contained would produce successful broods; the two unattacked samples were heavily attacked during the second week in March and by April 22 contained first and second instar larvae.

Five newly faded to just-fading trees examined November 30 contained Ips broods that were predominantly in the larval stage. One of the five trees examined contained feeding groups of Ips intermixed with those constructing egg galleries. Ten trees containing overwintering broods were examined the first week of April and the broods were found to be predominantly callow adults.

On the basis of these data, it is apparent that the current overwintering generation passed the winter most successfully in the callow adult stage.

Brood abundance

Records of seasonal broods in killed trees and in slash from February to November provide data on the abundance of Ips produced in 1948. Information was obtained on the abundance of adults successfully overwintered in trees as well as the numbers of mature broods produced in successive generations. Table 7 summarizes this data obtained by actual count of broods in field samples and by emergence records from caged infested sections of slash.

Table 7.--Brood Abundance Record for Ips--1948

Source	No. of Samples	Bark Area-- Sq. Ft.	Attacks: Per Sq. Ft.	Gallery Length Per Sq. Ft.	Brood Per Sq. Ft.	Brood Per Inch of Gallery
Overwintering Brood:						
Field count	12	28	9.2	58 in.	103.5	1.8
Emergence record	4	12	9.3	53 in.	87.2	1.6
1st Generation:						
Field count	5	7	27.2	113 in.	214.7	1.9
Emergence record	2	6	18.0	109 in.	184.5	1.7
2nd Generation:						
Field count	1	1	22.0	87 in.	212.0	2.4
Emergence record	5	15	13.0	95 in.	212.0	2.2
3rd Generation:						
Field count	2	2	10.5	64 in.	244.0	3.8
Emergence record	6	18	12.0	81 in.	204.0	2.5

The difference in figures obtained through field counts and emergence records of a similar material can probably be attributed to mortality occurring prior to actual emergence. Field counts are made on material in the field at the time when the brood stages usually consist of last instar, pupae, and callow adults, while emergence records pertain only to adults emerging from the infested material.

Table 7 shows that the average brood produced per square foot of bark increased from the relatively low brood per square foot manifested in the overwintering records to the relatively high brood count of the second and third generations. The number of pines killed by Ips followed the trend of brood size per generation rather closely with the greatest number of pines being killed during the flight and attack period of the second and third generations. Very limited data were obtained during April 1949 on brood abundance of the overwintering fourth and fifth generations. These data point to a drastic reduction in overwintering populations as compared with the previous overwintering brood.

Ratio of progeny to parents

Limited information on this factor among late summer broods revealed a ratio of 3.7. Data were taken from eight representative samples each containing three square feet of bark area; these samples represented four different areas in which killed trees were found. The average number of attacking beetles (variations of from 27 to 72) amounted to 43.3 per square foot of infested area, while the average progeny produced to maturity (variations of from 58 to 344) amounted to 161 per square foot. This may be a downward trend from maximum production, but no previous data have been taken in this area to establish a comparison standard.

RELATIVE IMPORTANCE OF RED TURPENTINE BEETLE

Further data were taken on the red turpentine beetle (Dendroctonus valens Lec.) in considering its possibility as a primary killer of living trees. A plot of 100 typically representative Coulter pines selected for periodic examinations between May and September revealed that five out of seven were attacked successfully. Thus, it was shown that the occurrence of the insect as a successful invader amounted to five percent of the trees examined. Later examination of the 100 trees in April 1949 showed that four of the five trees successfully attacked by red turpentine beetles had been killed by Ips and flathead attacks; the fifth tree had survived the red turpentine beetle attacks. The four trees that were killed probably were in a weakened state as a result of large cankers on the stems caused by a stem rust. Such a condition probably materially aided the successful establishment of red turpentine beetle attacks, which in turn resulted in Ips attacks that finally killed the trees.

In view of such information, it appears that Dendroctonus valens plays a minor role as a primary killer in vigorous Coulter pine but can successfully establish attacks in weakened Coulter pine.

EVIDENCE OF CONTINUING INFESTATIONS

Current evidence with regard to continuing Ips outbreaks points to a favorable slash material as a primary requisite for subsequent aggressive killing. In this respect, the Julian-Cuyamaca area was vulnerable to a continuing high Ips population in 1948. Three tracts in the area were being logged during 1948, and the slash created by these "shotgun" logging operations served as ideal breeding grounds for great numbers of Ips. A survey of current slash conditions in the Julian-Cuyamaca area carried on from April to September revealed that during this time approximately 1,100 acres had been cut, leaving from 6 to 14 tops per acre as slash. Conditions on the cutover land were most favorable for optimum Ips breeding, as the tops were unlopped and well shaded by the oaks and reserve Coulter pines. As a result, the slash produced heavy broods that eventually killed over 2,500 trees by December 1948.

NEED FOR FURTHER STUDY

During the last few years, the importance of Ips confusus as an aggressive killer in southern California pine stresses the necessity for further investigative work, especially with respect to seasonal history, habits, and ecology. Considerably more detailed information is needed on Ips behavior in hosts in this latitude where nearly all the pine areas are under recreational land use. This is needed as a basis for the development of sound, effective control measures.

Further information is needed on the effect of climatic factors both with respect to the beetle cycle and the host tree affected. The possibility of predicting potential Ips outbreaks through an analysis of climatic conditions is indicated.

The reason Ips prefer to attack certain trees and not others possibly can be attributed to physiological factors relating to host trees. Investigations are needed to determine if such physiological factors exist, how they arise, and what relation they have to incidence of Ips infestation.

The development of proper control techniques, either direct or indirect, should be studied to insure protection of the reserve pine stands in logging areas.

SUMMARY

In 1946 and 1947 a severe Ips outbreak in Coulter and Jeffrey pine of the Julian-Cuyamaca area, San Diego County, presented the opportunity for close study of the character of an engraver-beetle outbreak in this southerly part of its range and on a different host from those heretofore studied in detail. These studies were initiated in February 1948 and continued through October.

The most significant points as revealed by this study are:

1. Ips proved to be the genus of bark beetle responsible for most of the killing during the current outbreak. Approximately 92 percent of 118 trees sampled had been attacked and killed by Ips alone or in combination with other tree-destroying beetles.

2. The combination of severe drought conditions, reduced host vigor, and favorable slash material resulted in one of the most serious Ips outbreaks in a limited area in recent years.

3. A cumulative rainfall deficit of 46 inches has accrued over the past 19 years. 81 percent, or 37 inches, of the deficit has occurred during the past 7 years.

4. The months during which most tree growth takes place (January to June) show a deficit from the normally expected rainfall totaling 58 inches. 97 percent of this deficit, or 56 inches, can be accounted for in the last seven years.

5. An apparent correlation has existed between rainfall deficiency and bark-beetle outbreaks over the last 19 years.

6. Increment-core studies show a fairly close correlation between rainfall and diameter increment.

7. "Shotgun" type logging operations were working in the Julian-Cuyamaca area as early as 1942, and slash created by such logging operations provided optimum breeding conditions for Ips broods.

8. Limited data revealed an apparent preference for host species by the two species of Ips in the area. Ips confusus Lec. attacked Coulter or ponderosa pine, while Ips oregoni Eich. confined its attacks to Jeffrey pine.

9. The role of Dendroctonus valens Lec. as a primary killer in Coulter pine was investigated and the information gathered revealed D. valens to be secondary in this capacity during 1948.

10. Observations concerning the possibility that mistletoe and fungi were responsible for the weakening and eventual killing of the pines indicated that these factors might be of importance in localized areas, but were unimportant in the over-all picture and had little bearing on the current outbreak.

11. The overwintering period of 1947-1948 was passed mainly in the callow adult to adult stage. 89 percent of the overwintering Ips examined were in the adult stage, 8 percent in the pupal stage, and 3 percent in the larval stage.

12. A comparatively large overwintering Ips brood in 1948 emerged from the infested trees. Limited data revealed that 87.2 adult Ips emerged per square foot of infested bark area. Later data revealed the 1949 overwintering brood to be considerably smaller than the 1948 overwintering brood.

13. Ips pre-seasonal emergence, flight, and attack occurred in January 1948 as a result of unusually high temperatures (between 70 and 80 degrees F.) during the latter part of December and most of January. Normal emergence of overwintering broods began the latter part of March.

14. Ips flight, attack, and brood development occurred continually from the latter part of March through November of 1948.

15. Living trees, as well as fresh slash, were attacked all through the flight season.

16. Four complete Ips generations and a partial fifth were produced in 1948.

17. Emergence records involving 39 square feet of bark area indicated a fairly high brood population averaging 200 adults emerging per square foot of infested slash bark area during the season.

18. Late summer information on progeny in relation to parents indicated a ratio of 3.7.

19. A survey of cut-over lands revealed an ample supply of slash for breeding large Ips broods. 1,100 acres had been cut leaving 6 to 14 tops per acre suitable for Ips breeding.

20. Approximately 2,500 trees were killed by Ips during the period from April to December 1948.

21. Further investigative work should be conducted into the seasonal history, habits, and ecology of Ips confusus, especially with regard to developing proper control techniques.

FIGURE 1

DEPARTURE OF SEASONAL AND SPRING RAINFALL
FROM 50 YEAR AVERAGE
JULIAN, CALIFORNIA

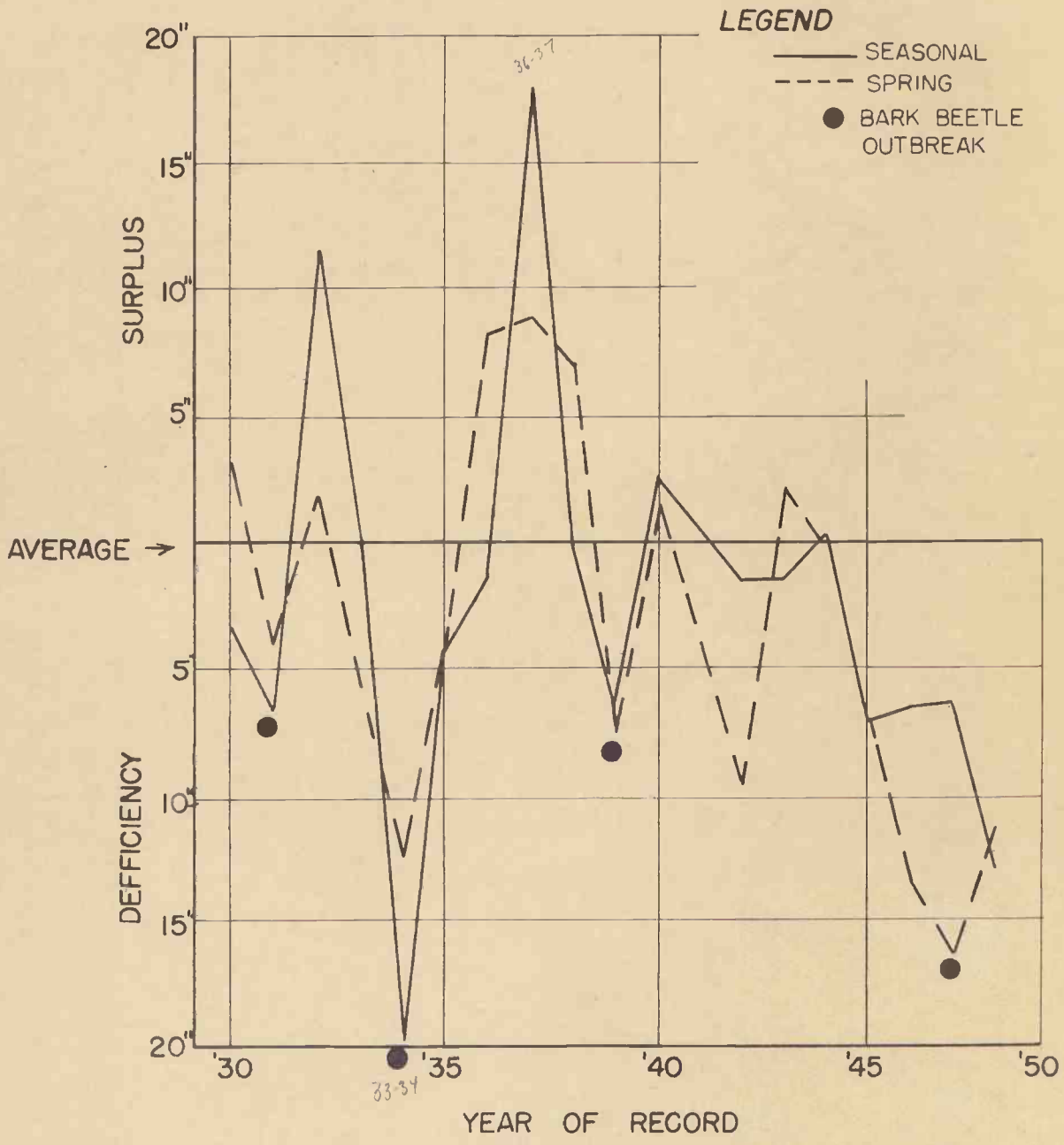

FIGURE 2

AVERAGE ANNUAL INCREMENT OF COULTER PINE
AS COMPARED WITH
ANNUAL RAINFALL DEPARTURE
1930-1949
JULIAN, CALIFORNIA.